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WASTE VEGETABLE OIL AS A FUEL EXTENDER.(U)
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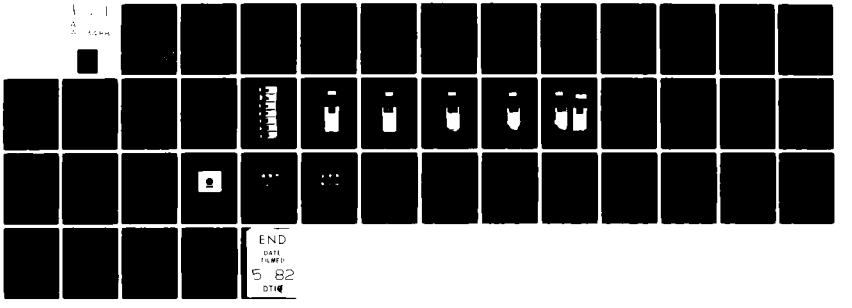

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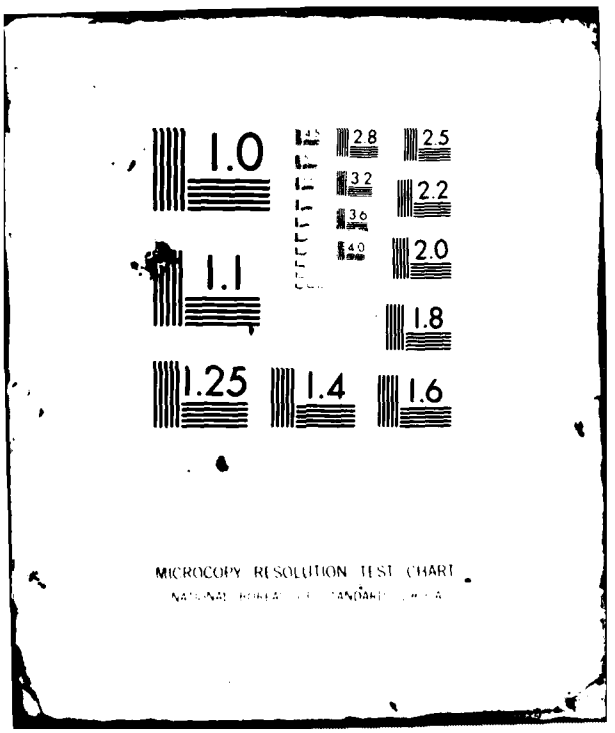
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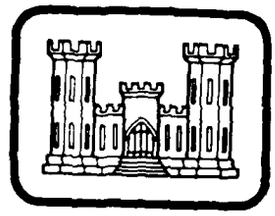

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FESA-T-_____

FINAL REPORT ON

WASTE VEGETABLE OIL AS A FUEL EXTENDER

James F. Thompson, Jr.

US Army Facilities Engineering Support Agency
Technology Support Division
Fort Belvoir, VA 22060

Approved for Public Release; Distribution Unlimited

Prepared for:
USA Facilities Engineering Support Agency
Technology Support Division
Fort Belvoir, VA 22060

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Report presents the conditions under which waste hydrogenated vegetable oil can be mixed with waste and virgin petroleum oils and remain in a homogeneous state.

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ABSTRACT

This report presents the conditions under which waste non or partially hydrogenated vegetable oil can be mixed with waste and virgin petroleum oils and remain in a homogeneous state.

TABLE OF CONTENTS

LIST OF TABLES

1.0 BACKGROUND AND INTRODUCTION

1.1 The precedent for using waste vegetable oil as a fuel extender was established at Ohio State University. Graduate students at Ohio State, under the guidance of Dr. Heimuth Engleman, conducted successful experiments using waste vegetable oil to run diesel engines. The waste vegetable oil used was a nonhydrogenated oil filtered to remove any particulate matter. The waste vegetable oil was mixed with No. 1 diesel fuel in a 20 percent vegetable oil to 80 percent diesel fuel ratio. This mixture was successfully tested in a Detroit diesel used to power a campus bus.[1][2]

1.2 Using this data base the Headquarters US Army Infantry Center, Fort Benning, GA identified a potential fuel source of 18,000 pounds (2,344 gallons) per month of waste vegetable oil from its various dining facilities. Because Fort Benning has been supplementing its standby boiler fuel with spent motor oil since 1972, it was conceivable that waste vegetable oil could be used in the same fashion with appropriate preparation.

1.3 Fort Benning wished to collect the waste vegetable oil from their dining facilities using a truck adapted for oil collection. This waste vegetable oil would then be mixed with other waste crankcase and fuel oil collected from the base. This mixture would then be stabilized with an additive, and then remain in a settling tank for no less than thirty days to remove any particulates which could clog or damage the boiler fuel filtering system. The fuel mixture would then be burned as is or mixed with new oil and burned.

2.0 PROGRAM OBJECTIVE

2.1 The objective of this program was to determine the conditions under which waste vegetable oil can be mixed with waste and virgin petroleum oils and remain in a homogeneous state.

3.0 PROGRAM APPROACH

3.1 The Army uses both hydrogenated and nonhydrogenated vegetable oils in its kitchens. The hydrogenated oil is used for cooking and the non-hydrogenated oil is used as salad oil. Therefore, the bulk of the waste oil is the hydrogenated type.

3.2 The hydrogenated oil is solid at room temperature (70F) and requires constant heating to stay in a liquid state. As previously stated, the work conducted at Ohio State University used non or partially hydrogenated vegetable oils which remain liquid at room temperature. Because of this difference it became necessary to evaluate both hydrogenated and non-hydrogenated vegetable oils. Therefore, the program approach chosen by the Facilities Engineering Support Agency (FESA) in conjunction with Fort Benning contained two evaluation phases. The first phase evaluated the hydrogenated oil and the second phase evaluated the nonhydrogenated oil.

3.3 The first evaluation phase was conducted by the Fuels and Lubricants Division of the Energy and Water Resources Laboratory at Fort Belvoir and Eastern Equipment and Chemical Company of Columbia, South Carolina. The test results from the Fuels and Lubricants Division are contained in Appendix A. No formal report was obtained from Eastern Equipment and Chemical Company; however, the results of their test work will be presented in this report.

3.4 The second evaluation phase could not be conducted by the Fuels and Lubricants Division due to internal manpower shortages. Therefore, the work was done by the Chemistry Research Group of the Materials Technology Laboratory at Fort Belvoir. The test results for the second evaluation phase are contained in Appendix B.

4.0 FIRST EVALUATION PHASE TEST RESULTS

4.1 The first evaluation phase was conducted on waste hydrogenated vegetable oil, obtained from one of the messhalls at Fort Belvoir, and No. 2 diesel fuel. The No. 2 diesel fuel was chosen because of its low opacity (light color/transparency) which aided in the detection of fuel stratification/separation.

4.2 The hydrogenated vegetable oil was mixed with the No. 2 diesel fuel in percentage rates varying from 2 to 50 percent by volume. This was done to determine the percentage mixture of vegetable oil to fuel oil at which no stratification/separation occurs. It was found that the only solution which stayed in suspension was the 2 percent hydrogenated vegetable oil to 98 percent No. 2 diesel fuel.

4.3 Recognizing that this is a very low percentage mixture, Eastern Equipment and Chemical Company was contacted by FESA to determine if there were commercially available additives which would keep the hydrogenated vegetable oil in solution at a higher percentage mixture. Eastern Chemical, using the same percentage mixtures as detailed in Appendix A, tested the hydrogenated vegetable oil with No. 2, No. 4, and No. 6 fuel oils and waste crankcase oil. After two weeks of testing, Eastern found that all of the oil mixtures separated with and without the use of additives.

5.0 SECOND EVALUATION PHASE TEST RESULTS

5.1 The second evaluation phase was conducted on waste and new non/partially hydrogenated vegetable oil and No. 4 and No. 6 fuel oils. The partially hydrogenated vegetable oil was mixed with the No. 4 and No. 6 fuel oils in percentages ranging from 10 to 50 percent by volume. Each sample mixture was subjected to the ASTM test shown below:

TEST DESCRIPTION	METHOD
Pour Point	D97
Viscosity	D445
Corrosion	D130
Flash & Fire Point	D92
Heat of Combustion	D240
Sulfur Analysis	D1552
Water & Sediment	D96
Heat of Combustion	D240

The results of the tests showed that the addition of nonhydrogenated vegetable oil to No. 4 and No. 6 fuel oils produced no deleterious effects. The detailed test results are contained in Appendix B.

5.2 In addition to the ASTM tests, compatibility tests were conducted to determine the degree of separation for each sample mixture. Two temperature zones, 32F and 75F, were examined as possible separation points. The compatibility tests showed that all samples were stable and no separation occurred at either temperature. The detailed test results are contained in Appendix B.

6.0 ECONOMIC ANALYSIS

6.1 A tabular display of the following economic analysis is presented in Table I. Based upon the heating values of the oils, 1.07 and 1.08 gallons of the vegetable oils are required to displace one gallon each of No. 4 and No. 6 fuel oils, respectively (see Table I).

6.2 The cost of No. 4 and No. 6 fuel oil ranges from $.97 to $1.00 per gallon. The waste vegetable oil (hydrogenated and nonhydrogenated) can be sold to food reprocessors who will use it as a protein enhancer in animal feed and dog food. The waste oil can be sold to the reprocessors for $.64 per gallon which is 66 percent of the market value for yellow grease. Therefore, the cost of the vegetable oils (hydrogenated and nonhydrogenated) to replace No. 4 and No. 6 fuel oils will be $.68 and $.69 per gallon respectively. Thus, using the vegetable oils as fuel extenders would save the government $.32 and $.31 per gallon for No. 4 and No. 6 fuel oil, respectively.

6.3 The vegetable oils are inexpensive fuels; however, use of the hydrogenated vegetable oil is not recommended because the percentage mixture, 2 percent hyrdrogenated vegetable oil to 98 percent fuel oil, make its use a marginal operation. For example, at Fort Benning only 200 gallons of fuel oil can be displaced by hrdrogenated vegetable oil in the 10,000 gallon mixing tank. This amounts to a savings ranging from $62.00 to $64.00 per 10,000 gallon tank of fuel. Therefore, the amount of money saved could be offset by collection and mixing costs.

6.4 The use of nonhydrogenated vegetable oil is recommended. Because of its physical properties, nonhydrogenated vegetable oil:

a. Remains fluid at room temperature, thus it is easier to collect and handle.

b. Remains in suspension in the fuel oils at a 50 percent by volume mixture, thus becomes cost effective as a fuel oil extender.

TABLE 1

ECONOMIC ANALYSIS TABLE

Oil Type	National Stock Number	Heating Value $\frac{X10^5}{Btu/gal}$	Cost ($/gal)	Value of Waste Vegetable Oil ($/gal)	Amount of Waste Vegetable Oil to Replace Fuel Oil (gallons)		Amount of Waste Vegetable Oil to Replace Fuel Oil ($/gallon)		Maximum Savings ($/gallon)	
					Hydro-genated	Non Hydro-genated	Hydro-genated	Non Hydro-genated	Hydro-genated	Non Hydro-genated
Hydrogenated Vegetable	0082	1.363	4.25	.64						
Nonhydrogenated Vegetable	8210	1.363	3.84	.64						
NO. 4		1.467	.97-1.00		1.07	1.07	.68	.68	.32	.32
NO. 6		1.463	.97-1.00		1.08	1.08	.69	.69	.31	.31

3a

6.5 Using the example of 6.3 above, the nonhydrogenated vegetable oil can displace up to 5,000 gallons of fuel oil. This amounts to a savings ranging from $1550.00 to $1,600.00 per 10,000 gallon tank of fuel.

6.6 As a side note USAFESA would like to point out that an additional savings of $.41 per gallon could be realized if nonhydrogenated vegetable oil were used for cooking instead of the hydrogenated vegetable oil.

7.0 CONCLUSIONS/RECOMMENDATIONS

7.1 As stated above, the waste hydrogenated vegetable oil can be used as a fuel extender; however, it is not recommended because it is a marginal operation.

7.2 It is recommended that:

a. Nonhydrogenated vegetable oil be used for cooking in Army post kitchens for a $.41 per gallon savings over the hydrogenated oil.

b. Waste nonhydrogenated vegetable oil be used as a fuel extender.

REFERENCES

1. Paula Ruth, Diesel and Waste Oil Mix Fuels Bus, Energy Users News, April 7, 1980, p. 16.

2. News In Engineering, Success in Trials of Diesel/Kitchen Fat Fuel, May 1980, p. 10.

LETTER REPORT

THE USE OF WASTE COOKING OIL AS AN EXTENDER OF FUEL

LUIS A. VILLAHERMOSA

OCTOBER 1980

Appendix A

THE USE OF WASTE COOKING OIL AS AN EXTENDER FOR FUEL.

I. Background

The Fuels & Lubricants Division; Energy & Water Resources Laboratory, has the responsibility to evaluate and qualify fuels and lubricants for the Department of the Army. Also any additive meant to be used as an improver or extender in fuels and/or lubricants are to be evaluated by this office prior to be considered for testing.

The use of used cooking oil as an extender in fuel of up to 20 percent has been addressed to U.S. Army Facilities Engineering Support Agency (FESA) in the form of a suggestion. Request was made to conduct a technical evaluation of the concept. The laboratory analyses and tests were requested to be performed by this office with a saturated vegetable oil supplied by FESA. A question arised on the types of cooking oil being used in the U.S. Army. Indications are that a great variety of cooking oil is being used by the Army in the U.S. This cooking oil ranges from fat; like lard, to saturated vegetable oils which are solid at room temperature.

Fuel oil No. 4 was not tested with cooking oil because of its high opacity (black color) which would not allow to have good test results especially in cloud point and solubility. The tests were performed only with DF2 since it was readily available.

II. Procedure

The cooking oil used for testing was a saturated vegetable oil which solidified at room temperature. This oil was obtained from the Messhall in Ft. Belvoir, VA.

Due to its solid state behavior the cooking oil had to be heated before mixing it with diesel oil. Three samples of 20, 30, and 50 volume percent cooking oil were made initially and subsequent samples made to pin point the concentration at which the cooking oil will stay in solution. After cooling down to room temperature, the temperature of the samples was recorded and notations whether it remains in solution or not were made.

The samples were then heated slowly until the cooking oil was dissolved. Other tests following ASTM methods were performed with only one concentration, 4 percent, since this was the maximum concentration where no separation occurred after 18 hours.

III. Results & Discussion

Table 1 shows the results of the miscibility test. The samples had to be heated and the diesel fuel kept warm while mixing it due to the solid state of the cooking oil at room temperature. The observations were made after the samples were allowed to cool overnight at room temperature (72-75 degrees F). The temperature of the samples at which the observations were made was 72 degrees F (22 degrees C).

Used Percent Volume Cooking Oil	Condition
2	No precipitation
4	precipitation
5	precipitation
10	precipitation
20	precipitation
30	precipitation
50	precipitation

Table 1

No precipitation was observed in the 2 percent sample and the 4 percent sample precipitated after 36 hours at room temperature (72-75 degrees F). The rest of the samples precipitated within hours after the mixing occurred. In figures 1 - 6, the separation that occurs could be observed in each of the samples.

It was also investigated at what temperature the used cooking oil will go back into solution once it precipitates, (Table 2). The samples were slowly heated with a continuous agitation until the cooking oil went into solution.

Used Percent Volume Cooking Oil	Temperature degrees F (degrees C)
2	---- ----
4	89.6 (32)
5	94 (32)
10	100 (38)
20	107 (42)
30	104 (40)
50	115 (46)

Table 2

The samples cleared up when heated but the 50 percent sample remained hazy even when heated at a higher temperature, 122 degrees F, (50 degrees C).

Additional tests comparing neat cooking oil, diesel fuel, and 4 percent cooking oil in diesel fuel are included in Table 3. The test results show an increase in the particulate concentration, cloud point, and pour point.

IV. Conclusions

The use of used cooking oil (saturated) as a fuel extender affected properties such as cloud point, pour point, and particulate concentration.

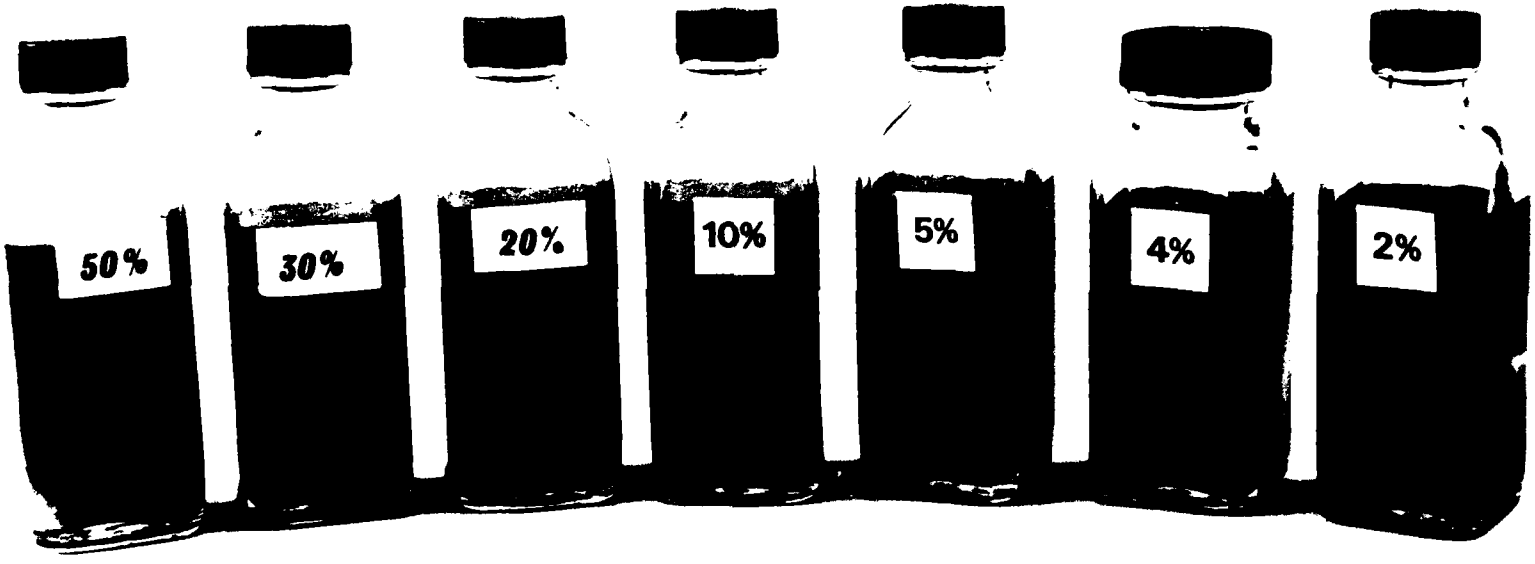


Figure 1
Group of Samples. Increase cooking oil concentration from right to left.

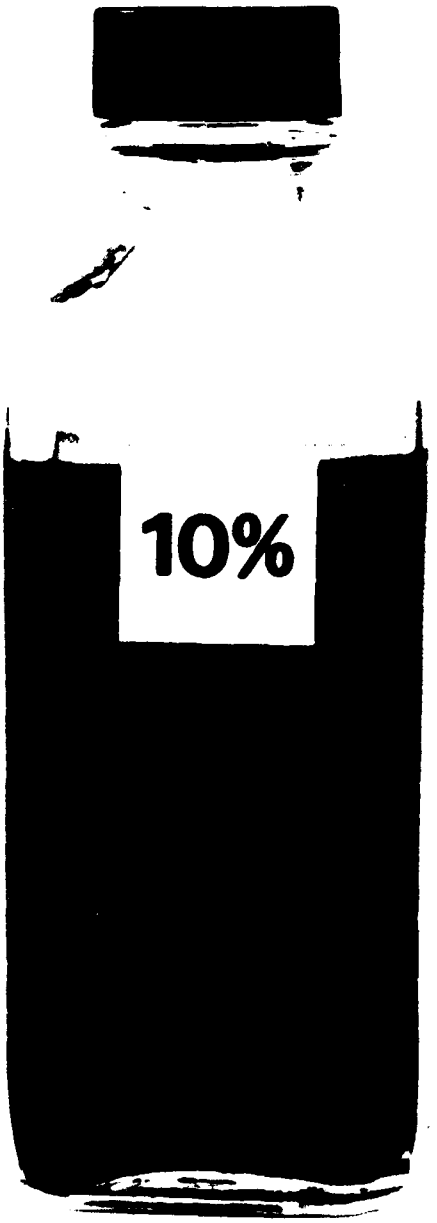


Figure 2
10% volume cooking oil in diesel.

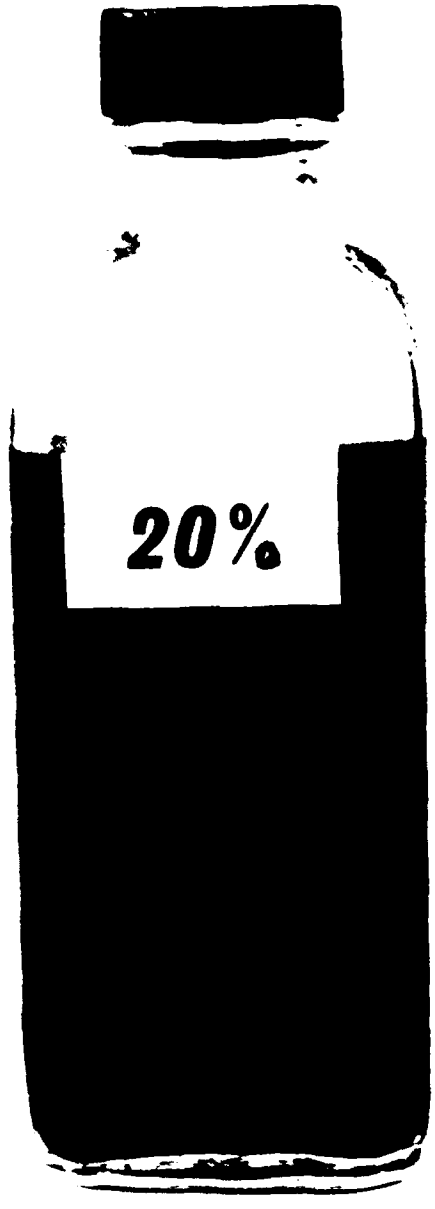


Figure 3
20% volume cooking oil.

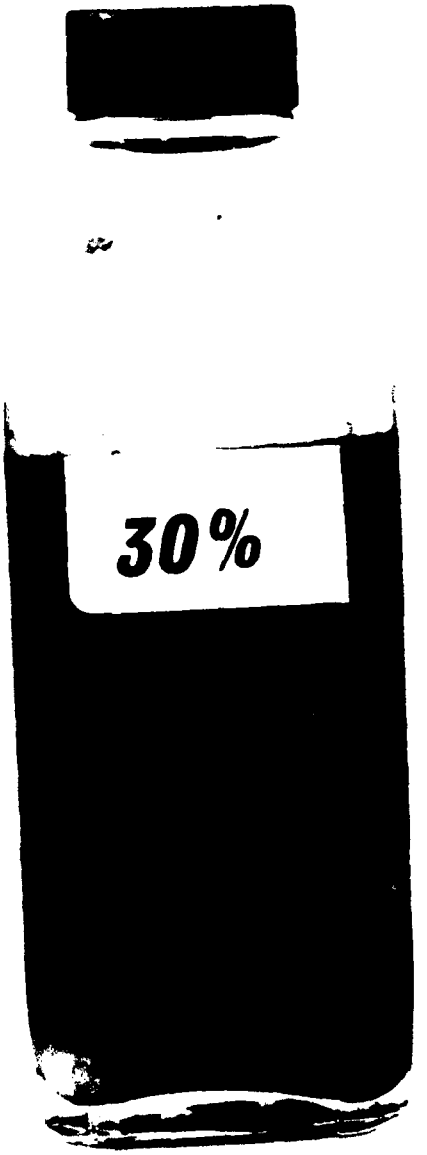


Figure 4
30% volume cooking oil.

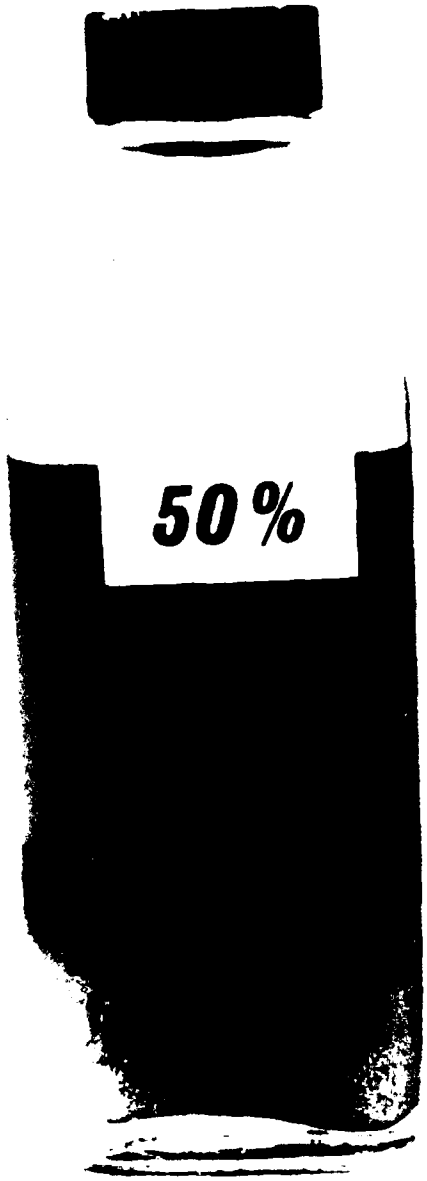


Figure 5
50% volume cooking oil.

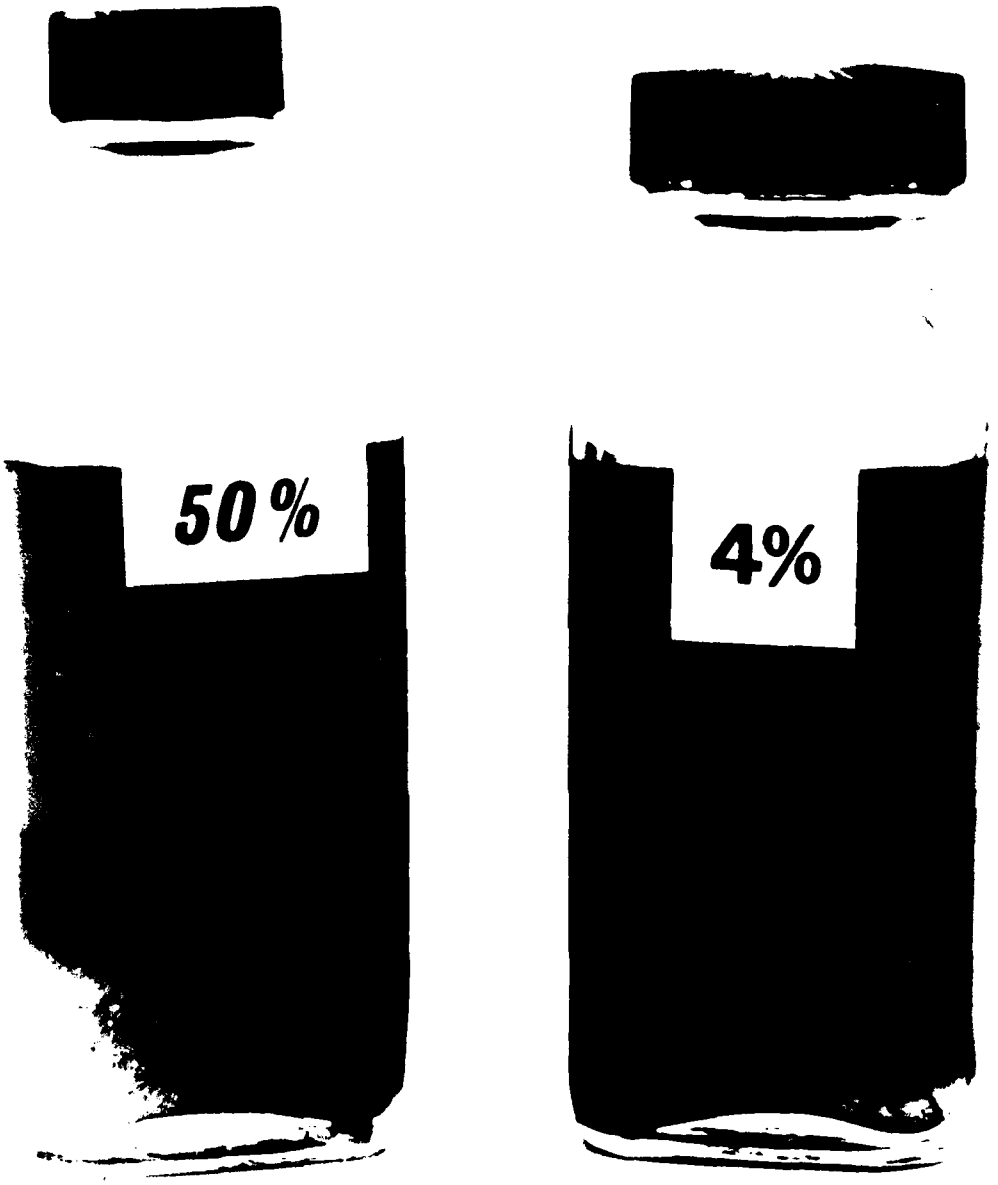


Figure 6
Comparison between 50% and 4% cooking oil.

TESTS	COOKING OIL (NEAT)	DIESEL OIL (NEAT)	DIESEL OIL + 4%/VOL. COOKING OIL
A.P.I. GR./60°F	-----	34.3	34.0
Particulate Cont. mg/1000 ml.	-----	19.97	178.71
% Carbon Res. 10% BTMS	-----	0.17	0.23
Copper Strip CORR. Rating	1A	1A	1A
Pour Pt., °F	+95	-20	-5&-10
Cloud Pt., °F	-----	+8	+2(
Flash Pt., °F	620	-----	-------
Fire Pt., °F	655	-----	-------
Vis. @ 40°C, cSt	5.1	2.8	3.1
Vis. @ 100°C, cSt	9.4	-----	-------
Heat of Combustion BTU/LB.	16950	19440	19340
DISTILLATION:			
INIT.		336	340
5%		394	396
10		424	430
20		458	463
30		480	484
40		498	504
50		516	522
60		534	540
70		552	558
80		574	581
90		601	618
E.P.		640	670
% REC.		99.0	99.0
CETANE INDEX		48.0	48.5

Table 3

These properties are important factors in fuel performance.

Solution made with more than 2 percent used cooking oil will precipitate within hours after mixing, which can create storage and startability problems (clog filters).

Analysis of the test results indicate that a concentration greater than 2 percent volume used cooking oil is not suitable as an extender for fuels.

V. Recommendations

The used cooking oil should not be used as an extender for fuels, unless the fuel will have continuous agitation and heated to temperatures above 107 degrees F.

DEPARTMENT OF THE ARMY
US ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA 22060

DRDME-VC

APPENDIX B

14 August 1981

FUEL OIL-VEGETABLE OIL COMPATIBILITY ANALYSIS

WORK ORDER NUMBER: 01270CEY

REQUESTED BY: FESA-T ATTN: J. Tompson

FUNDS: A1R14NSX081

1. The purpose of this work was to analyze fuel oil No. 4 and No. 6 with various concentrations of vegetable oil (10 -50%) for compatibility.

2. The tests performed are outlined in ASTM part 23, and are listed below:

TEST DESCRIPTION	METHOD
Pour Point	D97
Viscosity	D445
Corrosion	D130
Flash & Fire Point	D92
Heat of Combustion	D240
Sulfur Analysis	D1552
Water & Sediment	D96
Heat of Combustion	D240

Additional tests were performed as follows:

a. Compatibility Tests: All samples were placed in pour point jars; a controlled temperature bath was used for these at two specified ranges, 75°F + 2°F and 32°F + 2°F. The samples were conditioned for 15 minutes at each temperature range and observed for any separation.

b. Precipitation Tests: A one gram sample was dissolved in 100 grams of pentane, filtered through a millipore type AA, 0.8 micron paper. The residue was dried for 20 minutes at 105°C, cooled, reweighed and reported as percent residue.

Tests conducted with Fuel Oil No. 4 were mixed with new vegetable oil at concentrations listed in the Tables. Fuel Oil No. 6 was mixed with used vegetable oil and those concentrations are also listed. The used vegetable oil was heated for 2 hours, used as a frying medium then filtered so as to simulate field use.

DRDME-VC 14 August 1981
SUBJECT: Fuel Oil-Vegetable Oil Compatibility Analysis

3. The results are located in Tables I, II, III. The results of the compatibility tests indicate no visual separation of the fuel oil/vegetable oil concentrations at $75^{o}F$ or $32^{o}F$. The precipitation test (millipore residue) results were photographed and are inclosed.

4. It is concluded that there were no deleterious effects on the properites of No. 4 or No. 6 fuel oil/vegetable oil combinations as tested.

5. It is recommended that field testing of used vegetable oil/fuel samples be evaluated prior to system use.

Incls

SUBMITTED BY: BASIL ZANEDIS
A/C Chemistry Research Group
Material Technology Laboratory

FORWARDED BY: EMIL J. YORK
Chief
Material Technology Laboratory

TABLE I

SAMPLE DESCRIPTION	FLASH POINTS OF	FIRE POINTS OF	VISCOSITY CS			COPPER STRIP CORROSION	POUR POINTS OF
			32F	80F	100F		
No. 6 Fuel	315	370	--	959.6	375.2	1B	30
No. 6 @ 10% Veg Oil	265	345	--	519.4	223.9	1B	25
No. 6 @ 30% Veg Oil	280	380	--	255.8	126.4	1B	20
No. 6 @ 50% Veg Oil	330	425	--	163.6	82.8	1B	20
No. 4 Fuel	190	195	433.1	46.9	29.2	1B	-5
No. 4 @ 10% Veg Oil	200	220	351.6	49.3	30.8	1B	0
No. 4 @ 20% Veg Oil	200	225	339.2	49.8	31.0	1B	0
No. 4 @ 30% Veg Oil	215	230	336.6	53.1	31.4	1B	0
No. 4 @ 40% Veg Oil	220	240	317.1	56.7	35.4	1B	0
No. 4 @ 50% Veg Oil	220	255	275.1	56.8	35.9	1B	5
Veg Oil (New)	590	650	225.6	60.3	37.5	1A	15
Veg Oil (Used)	615	660	--	63.0	37.5	1A	--

TABLE II

	MILLIPORE RESIDUE	Mg/g	WATER & SEDIMENT (%)
No. 6 Fuel		76	2.8
No. 6 @ 10% Veg Oil		63	2.4
No. 6 @ 30% Veg Oil		58	2.0
No. 6 @ 50% Veg Oil		49	1.8
No. 4 Fuel		56	0.2
No. 4 @ 10% Veg Oil		62	0.2
No. 4 @ 20% Veg Oil		59	0.1
No. 4 @ 30% Veg Oil		51	0.0
No. 4 @ 40% Veg Oil		45	0.2
No. 4 @ 50% Veg Oil		31	0.4
Veg Oil (New)		1	0.0
Veg Oil (Used)		--	0.1

Note:

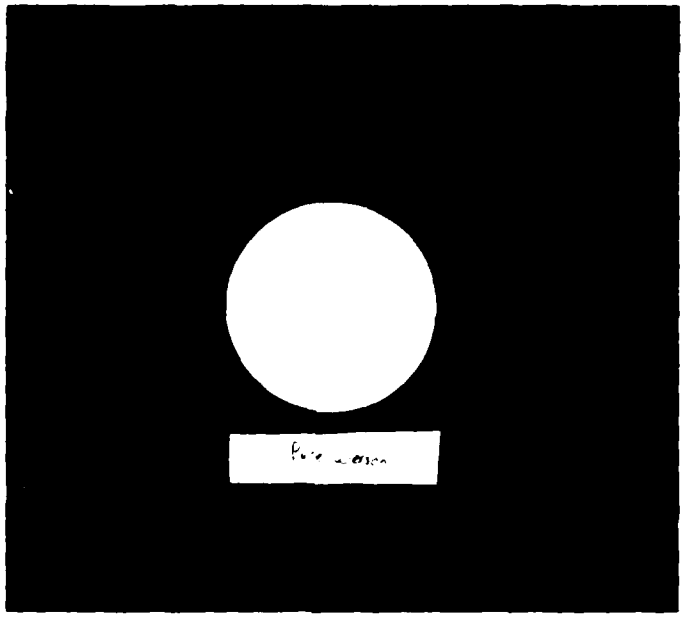
Millipore residue: 1 gram sample retained on 0.8 micron paper (Type AA)

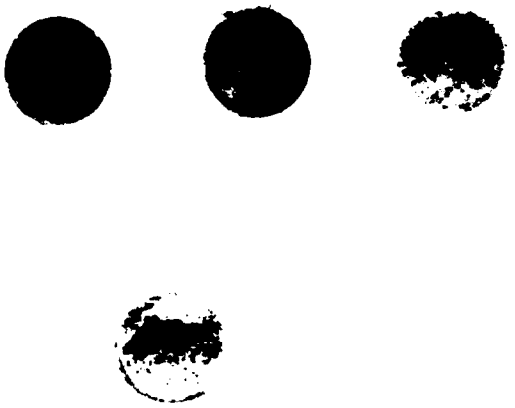
Centrifuge residue: 50 ml sample, 1:1 dilution with xylene

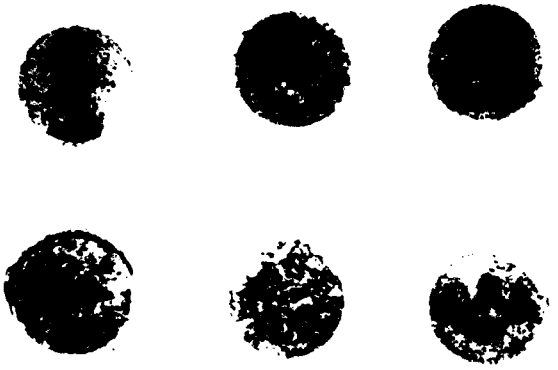
TABLE III

	HEAT OF COMBUSTION GROSS BTU/LB	SULFUR %
No. 6 Fuel	17756	.91
No. 6 + 10% Veg Oil	17756	.80
No. 6 + 30% Veg Oil	17743	.57
No. 6 + 50% Veg Oil	17363	.37
No. 4 Fuel	18745	.75
No. 4 + 10% Veg Oil	18180	.75
No. 4 + 20% Veg Oil	17764	.66
No. 4 + 30% Veg Oil	17794	.63
No. 4 + 40% Veg Oil	17689	.47
No. 4 + 50% Veg Oil	17352	.23
Veg Oil (New)	16343	.00

Note: The results obtained in each of the series runs are not always linear; this is attributed for both the nature of the samples and experimental error.







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